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Human Off-Road Mobility, Preference, and Target-Detection Performance with Monocular, Biocular, and Binocular Night Vision Goggles

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The present studies examined the hypothesis that participants who are required to scan for targets would perform better for a number of measures when wearing the monocular night vision goggle than when wearing biocular or the binocular goggles. These findings would be different from the findings discussed in the 1995 report in which participants were not required to scan for targets. No-moon and 3/4 moon experiments were conducted using National Guardsmen. The difficulties that each participant encountered while walking through rough, off-road terrain were recorded by an independent observer. The observer recorded the participant's course-traversal times and the number and types of targets detected. The studies also collected data about subjective preference for the three types of goggles. Results replicated the previous studies, which found that the binocular goggle yielded better performance and was preferred to the other two goggles. The monocular goggle, again, showed no consistent difference from the biocular goggle for any of the four sets of dependent measures. The addition of the target-detection task failed to change the relative ordering of the monocular goggle versus the biocular or binocular goggles.

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CONTENTS

HUMAN OFF-ROAD MOBILITY, PREFERENCE, AND TARGET-DETECTION PERFORMANCE WITH MONOCULAR, BIOCULAR, AND BINOCULAR NIGHT VISION GOGGLES

INTRODUCTION

This report describes two experiments designed to address questions raised by our 1995 report (CuQlock-Knopp, Torgerson, Sipes, Bender, & Merritt, 1995) that examined the effects on off-road mobility of three ocular configurations of night vision goggles (NVGs). The three ocular NVG configurations (monocular, biocular, and binocular) were also compared for subjective preference. The monocular configuration provided an intensified view of the environment to one eye, with the other eye having an unaided, naked eye, dark-adapted view. The biocular configuration allowed both eyes to share the same two-dimensional (2D) intensified image of the environment. The binocular configuration produced two different image-intensified views and thus provided stereoscopic depth cues. The three types of goggles are shown in Figure 1.

The experimental results of the previous studies indicated that participants moved faster and made fewer errors with the binocular NVG than with the other two types of goggles. The participants also preferred the binocular goggle to the biocular and monocular goggles. In general, there was no consistent, statistical difference between the biocular and the monocular goggles.

In the studies described in the 1995 report, we attempted to minimize the way-finding demands of the task by requiring participants simply to follow eye-level markers on trees throughout the course. We used this procedure to reduce the error variation (statistical noise) that might be attributable to differences among the navigational abilities of the participants. Reviewers of that report have suggested, however, that the marker-following aspect of our task may have influenced the relative standing of the monocular goggle. The marker-following component could have allowed the participants to confine their visual attention to the path and not to scan the environment in a manner that is representative of the scanning behavior of the infantryman when traversing off-road terrain on foot.

This criticism raises two hypothetical explanations for the relative ordering of the goggles given in our 1995 report. The first concerns the utility of the wide field of view (FOV) potentially available to the unaided eye. Because of the possible utility of the *unobstructed* FOV in the unaided eye, a monocular goggle might be expected to show an advantage in an environment that requires scanning for human-sized targets. The marker-following task in the 1995 report could have been performed effectively with less than a 40° FOV and without scanning if participants

focused only on the markers along the path. Hence, a higher scanning demand might change the relative ordering of the monocular goggle versus the biocular and binocular goggles.

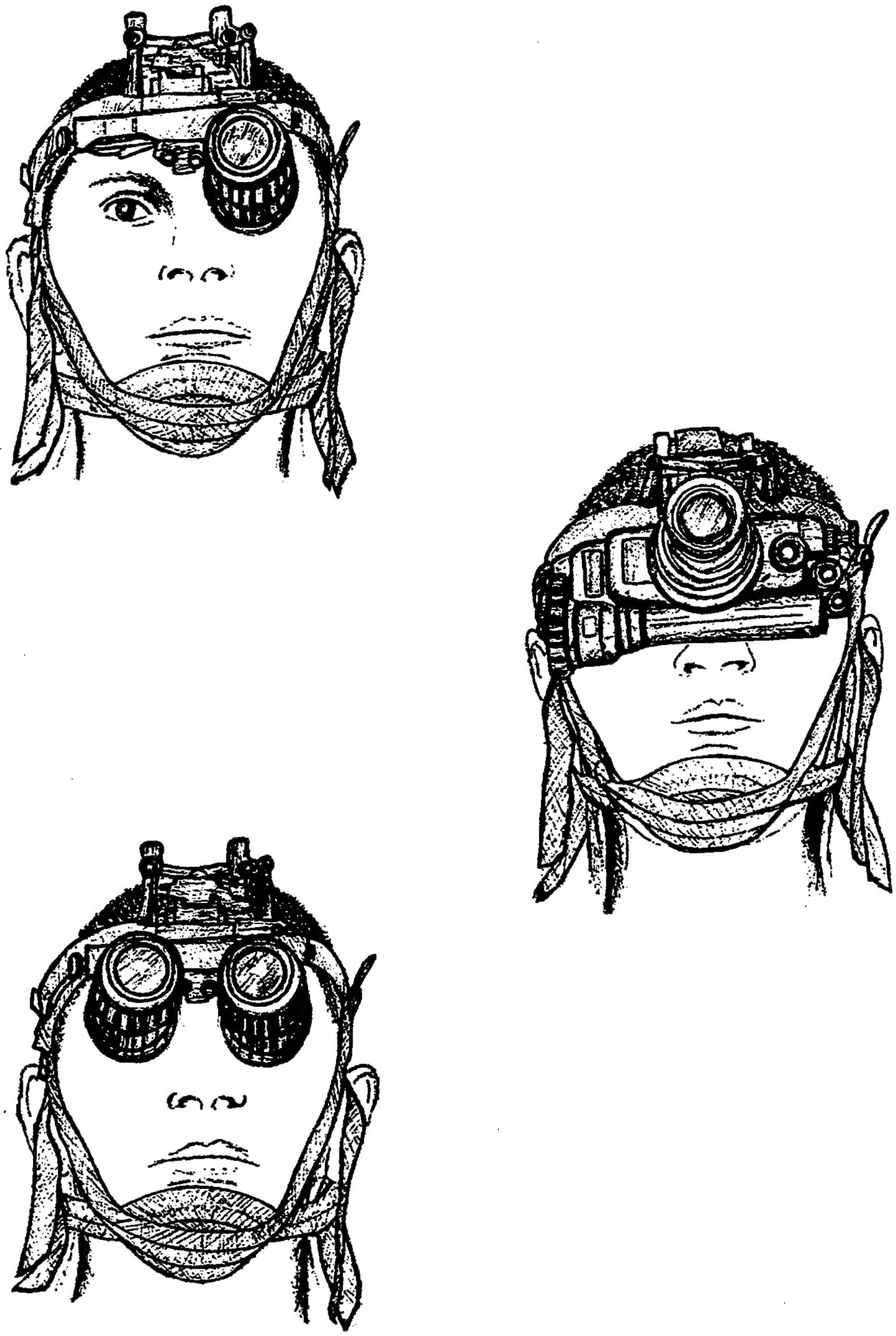

Figure 1. The head-mounted monocular, biocular, and binocular goggles worn by the participants.

The second explanation concerns the additional peripheral vision that is assumed to be more useful to the monocular goggle participant because of the dark-adapted state of the unaided eye. Physiologically, the light-adapted state in (and adjacent to) the central 40° FOV of the two eyes of the biocular and of the binocular goggle participants may limit their use of peripheral information. The monocular goggle user, on the other hand, has one unaided eye that is not only unobstructed but also is thoroughly dark adapted and consequently may have a higher probability of detecting targets outside the aided area covered by the NVG.

In the new experiments reported here, the task was modified so that the participants were required to detect targets at various distances to the side of the path that they followed across off-road terrain. This procedure forced the participants to scan to the right and left rather than to adopt a strategy of confining their visual attention to the well-marked path, thus simulating the scanning requirements of the infantry during off-road movement. In addition, the requirement to detect targets should also establish the conditions needed for a preliminary test of the hypothesis that extra peripheral vision in the unobstructed, dark-adapted eye improves performance of the dependent measures of errors, time, and subjective preference.

Regarding the last hypothesis, it is questionable whether people can employ the central and peripheral vision available to the unaided eye when there is a much brighter image in the central visual area of the other eye. This concern is partially a basic question about the threshold of sensitivity of one eye (the unaided eye) when the other eye is receiving stimulation of much higher luminance. This question relates exclusively to the sensory aspects of the problem and is mentioned here only to make explicit some assumptions that appear to have been implicitly held in arguments concerning the advantages of the monocular goggle.

One scenario used in discussions about the monocular goggle depicts a soldier who has a heightened sense of environmental awareness because of the dark-adapted state of the unaided eye. In some examples used in these discussions, this heightened environmental awareness is not limited to detecting only those objects that are of higher luminance or objects that move. (Note that the level of scene luminance in the aided eye is approximately 2000 times higher than in the naked eye.)

A number of relevant psychophysical studies have examined human vision capabilities but have not used a large luminance difference between the central area of the two eyes. Nonetheless, these studies provide information about scotopic stimulation, parafoveal detection, and luminance thresholds--topics that should enlighten the reader about the vision capabilities of

the unaided eye (see Uttal, Baruch, & Allen, 1994; Frumkes, Naaerendorp, & Goldberg, 1986; and Drum, 1981, for a sample). These psychophysical findings suggest it is unlikely that camouflaged, un-illuminated, static targets will be detected by the unaided eye when the monocular goggle is used. The present study is an empirical test of this proposition. To this end, we did not employ targets that were more luminous than the average forest background of the test site. To simulate the infantry environment, however, we also included moving targets, allowing us to evaluate the potential for heightened awareness in a realistic military scenario.

OBJECTIVES

The experiments were designed to provide data about two hypotheses: (1) the monocular configuration would show a greater utility with the addition of a task that requires scanning for targets, and peripheral vision in the unaided, dark-adapted eye would enhance performance during these conditions; and (2) evaluative ratings and rankings for the monocular goggle would be relatively higher than in the 1995 report.

METHOD

Test Site

No-moon and 3/4 moon experiments were conducted at Camp Finney of the Broad Creek Memorial Scout Reservation in Harford County, Maryland. The test area consisted of meadows and woods of mixed deciduous and coniferous trees with a variety of terrain hazards to foot travel, such as drop-offs, berms, and ditches.

Three different 1-kilometer courses (Course A, Course B, and Course C) were developed for the experiments. White, 9-inch circular plates were mounted on trees along the course to mark the path the participant should follow. Each plate had a rectangular piece of black tape added to it to improve the participant's ability to see the plates against the forest background as shown in Figure 2. On the average, the plates were 9 feet apart. All three courses were designed to be traversed in fewer than 30 minutes at night. The courses were also designed to provide adequate changes in terrain to allow ample opportunities to check hazard-avoidance performance.

Figure 2. An example of terrain used for the studies. Note the white circular plates marking the course.

A practice course was used to show the participants how the targets would appear against a forest background. The course was 100 feet long through a dense forest of sapling trees and bushes. One silhouette target was placed on the course.

Experimental Design

A Graeco-Latin square design was chosen to counterbalance the effects of four independent variables: goggle type, course, subject group, and order. Participants were randomly assigned to three groups. As shown in Figure 3, participants in Group 1 wore the biocular goggle for the first run, which was on Course C. For the second run, they wore the monocular goggle on Course B. For the third run, they wore the binocular goggle on Course A. Likewise, participants in Group 2 wore the monocular goggle first on Course A, and so forth. The entire Graeco-Latin square was completed twice each night for three successive nights of no-moon illumination. Eight days later, the same Graeco-Latin square was repeated with a new set of participants to assess performance during three successive nights of 3/4 moon illumination.

ORDER OF EXPOSURE TO THE THREE GOGGLE TYPES

	RUN 1	RUN 2	RUN 3
COURSE A	MONOC Group 2	BIOC Group 3	BINOC Group 1
COURSE B	BINOC Group 3	MONOC Group 1	BIOC Group 2
COURSE C	BIOC Group 1	BINOC Group 2	MONOC Group 3

Figure 3. The Graeco-Latin square design used for the experiments. (Groups 1, 2, and 3 are the three groups of participants used in the studies. Order denotes the sequence of exposure to the three goggles and courses. Goggles denote goggle type--monocular, biocular, and binocular. Course denotes which of the three courses [A, B, or C] is used. The Graeco-Latin square was repeated six times for the 3/4 moon illumination experiment and six times for the no-moon illumination experiment.)

Independent Variables

The independent variable of *goggles* had three levels: monocular, biocular, and binocular. This was the main variable of interest in these studies. The independent variables of *course*, *group*, and *order* are considered nuisance variables and were used in this design so that the variation in performance attributable to goggle type could be isolated from the variation in performance attributable to these unavoidable but irrelevant variables.

The course independent variable allowed us to assess the variation in human performance attributable to differences in the three courses. The group independent variable allowed us to assess the performance variation attributable to differences between subject groups, differences that would be expected to occur only by chance or by any effects related to specific combinations of courses, goggles, and ordering. The order independent variable allowed us to assess the variation in performance attributable to the order of exposure to each one of the three goggles.

One experiment using these independent variables was conducted during nights of no-moon illumination. Two typical no-moon illumination nights at the site were measured to have an average illumination of 4.5×10^{-4} footcandles, with measured values ranging from 2 to 7 $\times 10^{-4}$ footcandles. These values reflected a moderate degree of artificial light pollution. A second experiment replicated the same procedures during three nights of 3/4 moon illumination (the average light level was 5.7×10^{-3} footcandles). This illumination level was a nominal value inferred from previous measurements at 3/4 moon in the local vicinity.

Dependent Variables

Dependent Variable 1 (errors)

Eight types of errors were tallied by an independent observer (denoted as the "lane walker") who followed the participant as he traversed the course: (1) contact with an eye-level hazard, (2) contact with a ground-level hazard, (3) contact with a terrain contour hazard, (4) marked decrease in walking pace, (5) request for assistance, (6) stop, (7) stumble, and (8) other. Variable 1 is the total number of errors summed over all eight types made by the participant while he traversed the course.

Dependent Variable 2 (time)

Variable 2 is the total time taken by the participant in completing each course.

Dependent Variable 3 (ratings)

Variable 3 is the average of the participant's ratings of each goggle over seven individual items. Three of these items reflect the participant's rating of the warning afforded by the goggles in preventing his contact with eye-level, ground-level, and terrain contour hazard irregularities. One item reflects the utility of the goggles for target detection. The remaining three items reflect the participant's visual confidence, comfort, and his general feeling of the extent to which the goggles allowed timely forewarning of terrain hazards. Seven-point rating scales were used (1 was the lowest and 7 was the highest rating). These rating scales comprise Questionnaire A. Questionnaire A is included as Appendix A.

Dependent Variables 4 Through 9 (rankings)

Variables 4 through 9 consist of the participant's direct rank order of preference of the three goggles. The participants first ranked the three goggles for each of five specialized aspects of goggle utility: depth perception (Variable 4), level of comfort (Variable 5), target detection (Variable 6), hazard detection (Variable 7), and environmental awareness (Variable 8). The participant next ranked the goggles based on the instruction, "Write 'best' under your first choice of goggles to wear during a night mission; write 'worst' under your last choice." The response to this item was Variable 9. The participant recorded his rankings on Questionnaire B, which is included as Appendix B.

Dependent Variable 10 (steps)

Variable 10 is the number of steps taken by the participant to traverse each course. We hypothesized that there may be an inverse relationship between the number of steps taken by the participants and confidence. Steps that are smaller in stride but greater in number could indicate less confidence than steps that are larger in stride but fewer. Therefore, when the step scores are adjusted for individual stride length, the scores may indicate differences across participants in confidence levels, which would be expected to correlate with goggle preference.

Dependent Variable 11 (target score)

Variable 11 is the number of targets detected by the participant on each course.

PARTICIPANTS

Test Participants

Thirty-six male National Guard personnel between the ages of 24 and 54 were used as participants.

Lane Walkers

All the lane walkers were male and all but one of them were National Guardsmen. The civilian lane walker was a psychology graduate student who was an experienced orienteer. All lane walkers were trained in the use of NVGs. They were physically fit and had extensive orienteering experience through the National Guard or through personal experience.

Each lane walker was assigned to a specific course throughout the studies reported here. The tasks of each were to instruct and aid the participant in adjusting and focusing the goggles and then to follow him as he traversed the course. While doing this, the lane walker recorded the errors made by the participant, the time the participant took to complete the course, and the number and types of targets the participant detected. Each lane walker wore the binocular NVG (Aviator's Night Vision Imaging System [ANVIS]) while performing his lane-walking duties.

Interviewer

The interviewer was the person responsible for administering Questionnaires A and B to the participants.

APPARATUS

Night Vision Goggles

The three types of NVGs used for these studies were essentially identical in FOV (40° circular), resolution (0.8 cycle per milliradian), and magnification (1X). The biocular goggle was the AN/PVS-7B night vision goggle. The binocular goggle was the AN/AVS-6 ANVIS. The monocular goggle was an ANVIS with one ocular removed, so that the remaining ocular corresponded to the eye the participant selected to use for the goggle (i.e., the preferred eye). Both the binocular and monocular goggles were retrofitted so that they could use the same head mount as the biocular goggle.

The battery pack for the monocular and binocular goggles was affixed to the goggle shelf. The biocular goggle had an integral battery compartment. The total head-borne weights for the three types of goggles were monocular, 514 grams; biocular, 695 grams; and binocular, 735 grams. No eyecups were used on any of the goggles. Standard AA batteries were used; batteries were replaced at the beginning of each night of testing. Figure 1 depicts the three types of goggles as worn by the participants.

Human Targets

Two male civilians dressed in summer battle dress uniform (BDUs) served as moving targets for each course. Each human target moved to a different course location once per trial; therefore, each participant could detect a maximum of four human targets per course.

Inanimate Targets

Three silhouette figures dressed in summer BDUs were placed on each of the three courses. The BDU clothing was stuffed with plastic bubble wrap to fill the body of the target. Figure 4 shows an example of one of the inanimate (silhouette) targets in the forest setting.

Figure 4. An example of a silhouette target in the forest setting.

PROCEDURES

Preliminary

The lane walkers were trained in the error-scoring, timing, and target-detection procedures used during the test. Each of the lane walkers traversed the course assigned to him in the daylight to ensure his knowledge of the terrain and his knowledge of the locations of the targets. The authors conducted two pilot tests to give the lane walkers extensive experience in scoring and timing the participants and to determine the adequacy of the testing procedures.

Testing Procedures

Each set of three participants began the experiment with a stride test that required them to walk 100 feet while counting their paces. They then read and signed a consent form and then were tested for stereoscopic vision and at least 20/40 visual acuity. The Snellen chart was used to screen for the minimum acuity requirement, and a locally developed stereoscopic test was used to screen for the stereoscopic vision requirement.

Next, the participant entered the base-camp tent. (The tent was kept at a level of illumination low enough to permit dark adaptation.) The participants were shown all three types of goggles and informed about the purpose of the experiment and the procedures for focusing and adjusting the goggles. They were also given a safety briefing concerning traversing off-road terrain at night. Each participant then donned the type of goggle appropriate for the first run in his group assignment. At this time, the participants were given an extensive briefing about adjusting and focusing the goggles; each of the lane walkers then assisted the participants in fitting and adjusting the goggles. The monocular goggle participant was allowed to choose the eye to be aided by the goggle and was required to wear safety glasses to protect his unaided eye while walking in the woods.

Each participant then went outside where he used a second Snellen vision chart to check and readjust, if necessary, the focusing of the goggles. Next, each participant followed his lane walker to the practice course and traversed it. (The participant traversed the practice course one time only, before his first course.) Next, the participant went to the starting point of Course A, B, or C. An experimenter placed a zeroed pedometer on his ankle. The pedometer recorded the number of steps taken by the participant. The lane walker gave the direction to the participant to start traversing the course as quickly as possible without missing any targets. The participant was not told how many targets were on each course. The lane walker started a stopwatch as soon

as the participant took his first step, and he recorded the time taken by the participant to complete each segment of the course on a score sheet. The lane walker also noted on the score sheet each instance of an error (stumbles, stops, etc.) made by the participant in completing the course and the number and type of targets detected. (This score sheet is included as Appendix C.)

After finishing the course, the participant returned to the tent area where his pedometer reading was recorded. The participant and the lane walker then returned to the base-camp tent.

The interviewer administered Questionnaire A to the participant to record his subjective ratings of the goggles. He then put on his next goggle and followed his new lane walker outside to repeat the focus check using the Snellen vision chart. His pedometer was zeroed and he began the next course. This procedure was repeated until all three courses, along with their associated Questionnaire A forms, were completed. Following this, the participant completed Questionnaire B, the questionnaire used to rank the goggles. After this questionnaire was completed, the participant's eye dominance was measured. (Eye dominance was measured last so that the result of this test would not persuade the participant to place the monocular goggle on the eye that tested as dominant.) The participant's performance in this experiment was completed after this test.

The participant was paid a total of $75.00 for his services. The $75.00 included $50.00 for this test and $25.00 for another experiment that was completed later that night. A chart showing the sequence of events for a set of three test participants is presented as Appendix D.

Two sets of three participants were tested each night. The second set of participants began their testing immediately after the first set of participants left the camp. Hence, six participants were tested per night. There were three successive nights of testing in this format for the no-moon illumination experiment; 8 days later, there were three successive nights of testing in this format for the 3/4 moon illumination experiment.

RESULTS

Objective Measures

Separate sets of planned orthogonal contrasts for the dependent measures were performed. The independent variables were goggle type, course, order, and groups. The comparison of main interest was the binocular NVG versus the other two NVG types. The

second comparison was the monocular versus the biocular goggle. Separate planned orthogonal contrasts were run for the no-moon and 3/4 moon experiments.

Errors

Tables 1 and 2 present a summary of the number of errors for each type of error recorded by the lane walkers, summed across participants. Table 1 shows the no-moon illumination data, and Table 2 shows the 3/4 moon illumination data.

In the no-moon illumination experiment, consistent with the 1995 report, significantly fewer errors were made when the binocular goggle was worn than when the participants wore either of the other two types of goggles, $F(1, 45) = 6.25$, $p = .02$. There was no significant difference in performance between the biocular goggle and the monocular goggle, $F(1, 45)=.25$, $p = .62$.

Table 1

No-Moon Experiment
Number of Errors as a Function of Goggle Type and Type of Error

	Goggle type		
Error type	Monocular	Biocular	Binocular
Eye	44	39	37
Ground	84	80	59
Terrain	23	18	16
Slowness	83	73	51
Assistance	17	15	8
Stop	73	76	41
Stumble	24	18	19
Other	8	13	10
Total	356	332	241
Mean	19.8	18.4	13.4
N=18			

Table 2

3/4 Moon Experiment
Number of Errors as a Function of Goggle Type and Type of Error

	Goggle type		
Error type	Monocular	Biocular	Binocular
Eye	30	24	40
Ground	66	48	57
Terrain	14	10	9
Slowness	50	52	34
Assistance	0	2	0
Stop	41	32	23
Stumble	14	16	6
Other	4	5	6
Total	219	189	175
Mean	12.2	10.5	9.7
N=18			

In the 3/4 moon experiment, in contrast to the 1995 report, differences in the number of errors made by participants among the three goggles did not reach significance at the .05 level, ($F\ (1, 45) = .59, p = .38$ for the binocular versus the other two goggles and $F\ (1, 45) = .65, p = .43$ for the difference between the biocular and the monocular goggles). The present studies and the studies discussed in the 1995 report are not inconsistent, however, with regard to numerical ordering of the goggles--binocular with the fewest errors, biocular and monocular with the most errors. The summary tables for the all contrast analyses (for Errors, Time, Ratings, and Targets) are presented in Appendices E through I.

Time

Table 3 presents mean elapsed times in minutes for each of the three goggle types. Planned orthogonal contrasts were also conducted for differences among the goggles in time to complete the course.

In the no-moon experiment, the contrast analysis of goggles showed a significant difference between the binocular goggle and the two other goggles, $F(1, 45) = 7.31, p = .01$, with no statistically significant difference between the biocular and the monocular goggles, $F(1, 45) = .30, p = .58$.

In the 3/4 moon experiment, again as in the studies of the 1995 report, no time differences reached significance at the .05 level (binocular versus the biocular and monocular goggles, $F(1, 45) = .24, p = .63$, and biocular versus the monocular goggle, $F(1, 45) = 1.04, p = .31$). The overall numerical ordering of the goggles for the time measure is the same as in the 1995 report.

Table 3

Mean Elapsed Times (in minutes) as a Function of
Goggle Type and Amount of Moonlight

	Goggle type		
Moonlight	Monocular	Biocular	Binocular
No moon	29.03	27.73	22.89
3/4 moon	19.54	22.80	19.81
Means	24.29	25.27	21.35

Targets

In all but one marginal instance, no significant differences among the goggles were found for target detection. Planned orthogonal contrasts were performed on the moving target data and on the silhouette target data. The percentages of targets detected are presented in Table 4. For the human targets in the 3/4 moon experiment only, participants detected more targets when they wore the monocular goggle than when they wore the biocular goggle, $F(1,45) = 4.84, p = .03$.

Table 4

Percentages of Targets Detected

Moonlight	Goggle type: Monocular	Biocular	Binocular
	Silhouette*		
No moon	50%	35%	52%
3/4 moon	66%	59%	68%
	Human**		
No moon	55%	55%	55%
3/4 moon	70%	50%	72%

*maximum targets possible = 3; **maximum targets possible = 4

Steps

The "steps" variable was not analyzed because the pedometers were too unreliable and error prone to merit statistical analysis.

Descriptive Data

In contrast to the 1995 report, the participants in the present studies were allowed to choose the eye to be aided by the monocular goggle. Twenty-one of the 36 participants preferred the right eye and 15 preferred the left eye. The participants' eye dominance was tested using the Finger Aiming Test. Twenty of the participants tested as right eye dominant, twelve as left eye dominant, and four as neither right or left eye dominant.

For the 32 participants who tested as either left eye or right eye dominant, a Cramer's V statistic was calculated to determine the independence of the cross-tabulation of the two variables--"eye chosen" and "eye dominance." The results indicated a significant degree of association between these two variables (Cramer's V= .41, p =.02). Thus, eye preference and eye dominance were significantly, although not completely, related to each other.

A Cramer's V statistic was also calculated to determine the independence of the cross-tabulation of the two variables--"goggle experience" and "preferred goggle." The results indicated that there was no relationship between the amount of previous experience and the goggle selected as the preferred goggle (Cramer's V = .19, p =.62).

Nuisance Variables

As expected from the results described in the 1995 report, some of the main effects for the nuisance variables reached statistical significance at the .05 level of significance. The complete analysis of variance (ANOVA) tables (which include the main effects for the nuisance variables) are given in the appendices.

Evaluative Ratings and Rankings

The goggles were *rated* on 7-point scales (1 = poor, 7 = good performance) for seven qualities: the warning afforded by the goggles in preventing the participant's contact with (1) eye-level hazards, (2) ground-level hazards, (3) terrain contour hazard irregularities, (4) target detection, (5) confidence, (6) visual comfort, and (7) general feeling that the goggles allowed timely forewarning of terrain hazards. The seven individual items in Questionnaire A were summed to obtain a single score for each participant for the entire questionnaire. The averages of each of the seven questionnaire items for each of the goggles for the no-moon and 3/4 moon experiments are shown in Figure 5.

The average of the ratings of the seven qualities was analyzed using the same contrasts as used for the error and time measures. During both the no-moon and 3/4 moon illumination experiments, the binocular goggle was rated significantly higher than the biocular and the monocular goggles, $F(1, 45) = 24.75$, p =.001 (no moon) and $F(1, 45) = 17.96$, p = .001 (3/4 moon). The monocular goggle and the biocular goggle again showed no statistically significant differences in the average ratings for either the low moon or the 3/4 moon experiments, $F(1, 45)$ = .98, p = .33 (no moon) and $F(1, 45) = 2.4$, p =.13 (3/4 moon). These results are essentially the same as the results discussed in our 1995 report.

After the participant finished his third course, he was asked to *rank* each goggle relative to the other two goggles for five aspects of goggle utility: depth perception, level of comfort, target detection, hazard detection, and environmental awareness. One additional ranking was made to obtain the overall preferences of the participants. The participant was asked to write a

response to the item "Write 'best' under your first choice of goggles to wear during a night mission; write 'worst' under your last choice."

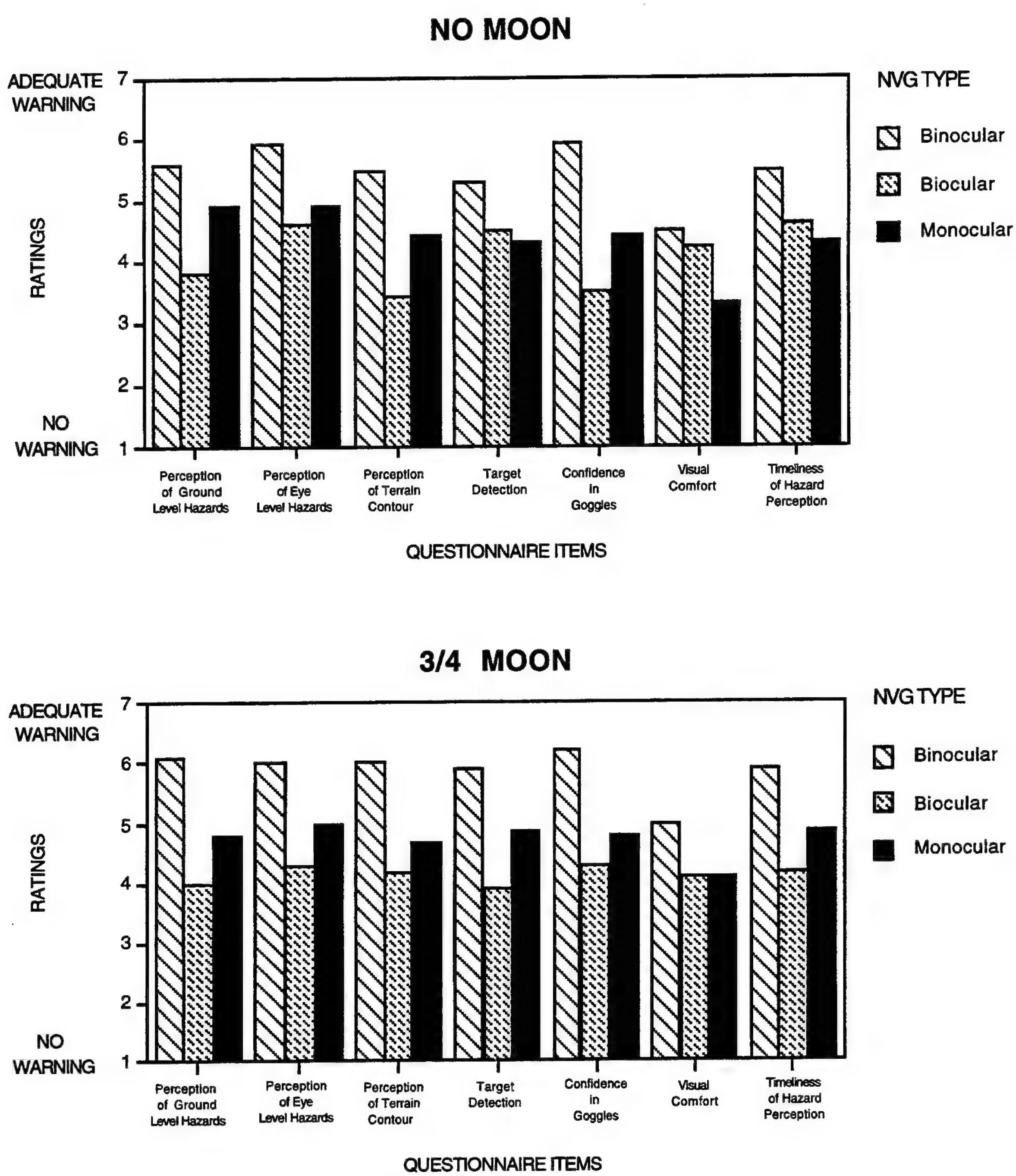

Figure 5. The average, across participants, of each of the seven Questionnaire A items for the monocular, biocular, and binocular NVGs for the no-moon and 3/4 moon experiments.

During the no-moon experiment, no significant differences among the ranks of the three types of goggles were found for "level of comfort," the overall comfort comprising visual comfort and comfort related to the fit and weight of the goggles. On all other ranking measures, the binocular goggle was preferred to the other two types of goggles and there was essentially no difference between the monocular and the biocular goggles. The results of the no-moon and 3/4 moon Friedman tests of significance are provided as Appendices J and K. The averages, across participants, of each of the six questionnaire items and for each type of goggles are shown in Figure 6.

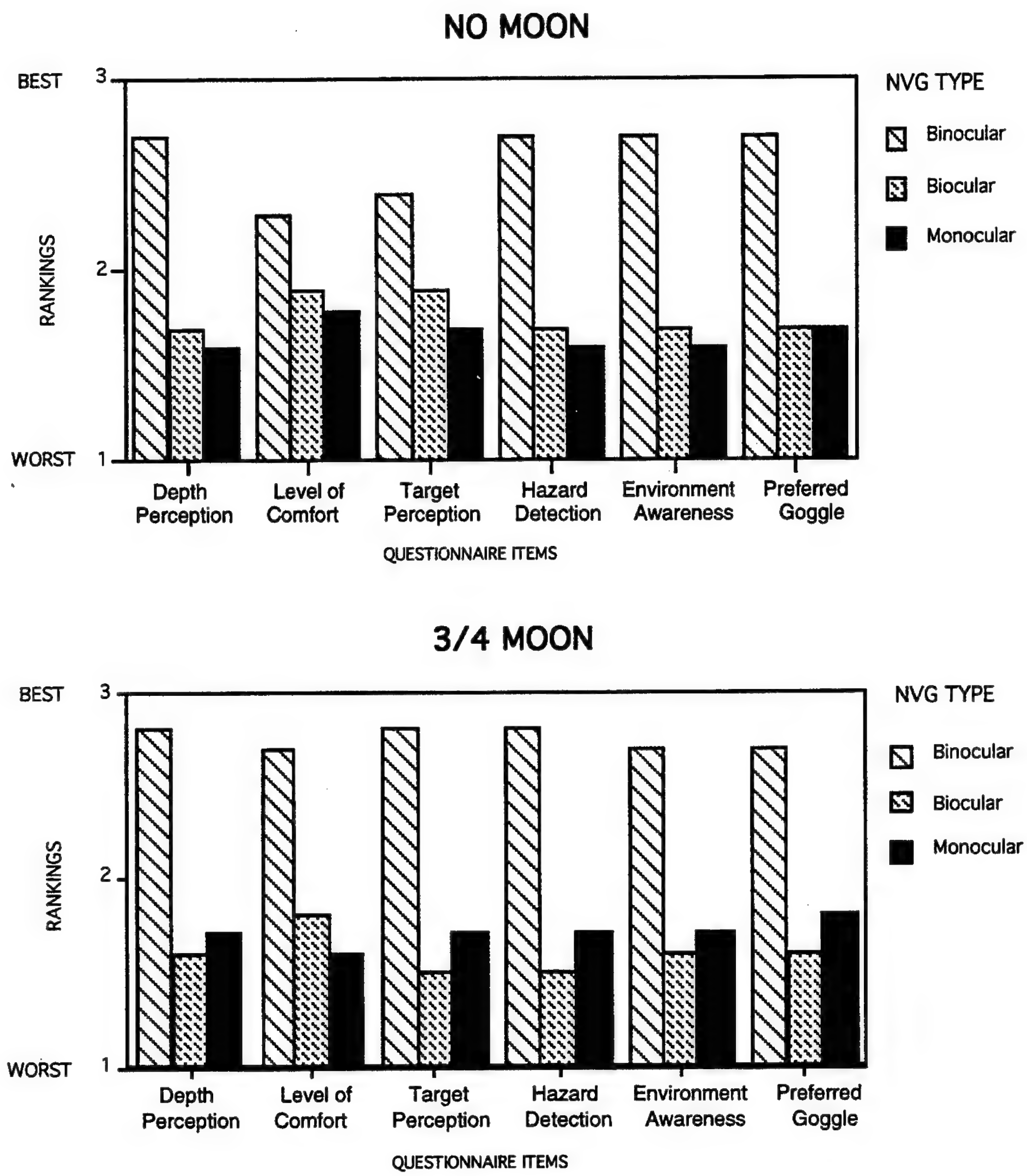

Figure 6. The average, across participants, of each of the six Questionnaire B items for the monocular, biocular, and binocular NVGs for the no-moon and 3/4 moon experiments.

DISCUSSION

Principal Findings

In the studies described in the 1995 report, the participants' performance using the monocular goggle was not consistently different from their performance using the biocular goggle. Significantly better performance occurred only when the participants wore the binocular goggle. In the present studies, we added a target-detection task to our test procedures in an attempt to force the participants to scan the environment as they traversed the terrain and to provide reasons for them to use the wide unobstructed FOV when they wore the monocular goggles. If the absence of a scanning requirement accounted for the ordering of the monocular goggle as discussed in our 1995 report, the presence of the target-detection task in the present studies should have produced a positive change in relative performance for the monocular goggle for some or all of the four principal sets of dependent measures.

A positive change in the ordering of the monocular goggle would have been indicated by one of three alternatives: (1) consistently better performance with the monocular goggle than with the biocular goggle; (2) performance with the monocular goggle equivalent or better than performance with the binocular goggle; (3) performance with the monocular goggle better than with either of the other two types of goggles.

The actual results indicate that the requirement to scan for targets failed to change the relative ordering of the monocular goggle on any of the principal dependent measures. In the no-moon experiment, the binocular NVG was superior to the other two types of goggles on the "errors" dependent measure; the monocular and the biocular goggles were not statistically different from each other. In the 3/4 moon experiment, although none of the main effects for goggles reached significance, the numerical ordering of the goggles was the same as discussed in the 1995 report.

The ordering of the goggles for the dependent measure, time, was also the same as discussed in the 1995 report. Participants were faster when wearing the binocular goggle than when wearing the biocular or the monocular goggles. There was no significant difference in participants' performance when they wore the biocular goggle than when they wore the monocular goggle. As with the "error" measure, no main effects for goggles reached significance at the .05 level in the 3/4 moon experiment.

The pattern for the ratings and the rankings (the subjective measures) is remarkably similar to the pattern discussed in the 1995 report. Highly significant results indicated that the binocular goggle was rated and ranked higher than the biocular and monocular goggles. Again, no significant differences were found between the monocular and biocular goggles.

As would be expected from variation attributable to chance, the monocular and biocular goggles change ordering for the ratings and for some of the various aspects of goggle utility. A post hoc, paired comparison analysis of the monocular and biocular goggles was performed to determine if there were any differences in these two goggles for the subjective measures as a function of moon illumination. Again, the results indicated no statistical difference between the monocular and biocular goggles.

The error variance in the present studies was considerably larger than that for the studies of the 1995 report. We believe the increase was attributable to the addition of the target-detection task and the increased difficulty of the terrain at Camp Finney (the test site of the present studies) compared to Camp Saffran (the test site of the 1995 report). With regard to the target-detection task, participants were forced to divide their attention between negotiating terrain and detecting targets. Some participants appeared to prioritize finding targets and others appeared to prioritize increasing speed or minimizing errors in traversing the terrain. Individual differences in task prioritization add increased error variance (noise) to the analysis, thus decreasing the sensitivity of the statistical tests.

In another effort to respond to criticisms of the studies of the 1995 report, each participant was allowed to place the monocular goggle on the eye he preferred. It had been proposed that forcing the participant to place the goggle on the right eye only may have negatively influenced the 1995 results, assuming that at least some of the participants were left eye dominant. This change also had no impact on changing the ordering of the monocular goggle relative to the other goggles.

Ancillary Findings: Moon illumination

In general, moon illumination did not affect the ordering of the goggles on the dependent measures. However, when the participants wore the monocular goggle, they detected more targets than when they wore the biocular goggle during the 3/4 moon experiment, whereas no such effect was found in the no-moon experiment. Also, more differences among goggle types failed to reach statistical significance during the 3/4 moon experiment in the present studies than

in the 1995 report, but the numerical ordering of the goggles was the same: the binocular goggle had the best performance, and there was essentially no difference between the monocular and the biocular goggles.

Ancillary Findings: Comparisons of Experiments

Table 5 shows the ranks of the three goggles in the studies of the 1995 report and the ranks of the goggles in the present studies. A rank of "3" represents the best ranking, "2" the middle ranking, and "1" represents the worst ranking. Goggle types were found to be significantly different from each other in both studies. Mean rank orders of preference were also the same for both studies. The requirement to scan for targets did not change the ranking of the monocular goggle from its position when there was no such requirement.

Table 5

Mean Ranks of the Goggles in the Previous and Current Studies

	Rankings	
Goggle type	Camp Saffran	Camp Finney
Monocular	1.63	1.69
Biocular	1.80	1.64
Binocular	2.57	2.69

Table 6 shows the paired comparison data for the goggles for both sets of studies. All the choices involving the monocular goggle reveal that participants' preferences are essentially identical across the two sets of studies for the three types of goggles.

Ancillary Findings: Post Hoc Questionnaire

During the initial briefing of the results of this research, it was suggested that our procedure of allowing the participants to choose which eye would be aided by the monocular goggle may not have been effective because a participant might not be able to make that type of judgment until he actually starts to traverse the course wearing the monocular goggle. Therefore, had we given participants the option to change which eye was aided, they may have changed their opinions about the monocular goggle.

Table 6

Paired Comparisons of Monocular, Biocular, and Binocular Goggles

Overall Ranking of the Three Goggles		
	Camp Saffran	Camp Finney
Binocular preferred to biocular	24 to 11	31 to 5
Binocular preferred to monocular	31 to 4	31 to 5
Monocular preferred to biocular	18 to 17	17 to 19

In response to this claim, we developed and sent a two-item questionnaire to each participant in the studies. (The questionnaire was sent approximately 2 months after the studies were completed.) Item 1 asked, "Once you began traversing the course, were you satisfied that the eye you selected was the eye you should have selected?" Item 2 asked, "Do you now feel that you would have favored the monocular goggle if you had placed the goggle on the eye you did not choose?"

Thirty-four of 36 participants returned the questionnaire. In response to Item 1, all but one of the participants indicated that they did not want to change the eye that they originally selected and all but one responded "no" to Item 2.

SUMMARY

Two general conclusions can be drawn from the present no-moon and 3/4 moon experiments: (1) adding the target-detection task did not change the ordering of the goggles on any of the major dependent measures in the two studies, and (2) the binocular goggle continued to be superior to the biocular and monocular goggles, and there were no important differences between the monocular and biocular goggles in either performance or subjective measures.

REFERENCES

CuQlock-Knopp V.G., Torgerson W.S., Sipes D.E., Bender E., & Merritt J.O. (1995). A comparison of monocular, biocular, and binocular night vision goggles for traversing off-road terrain on foot (Technical Report ARL-TR-747). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Drum B. (1981). Brightness interactions between rods and cones. Perception and Psychophysics, 29, 505-510.

Frumkes, T.E., Naarendorp F., & Goldberg, S.H. (1986). The influence of cone adaptation upon rod mediated flicker, Vision Research, 26, 1167-1176.

Utall, W.R., Baruch, T., & Allen L. (1994). Psychophysical foundation of a model of amplified night vision in target detection tasks. Human Factors, 36, 488-502.

APPENDIX A

QUESTIONNAIRE A

Questionnaire A

On the following scales, circle the number that best represents your response.

Rate how well the goggles performed in helping you to see ground-level hazards such as stones, fallen logs, holes, roots, and streams.

1 2 3 4 5 6 7

(no forewarning) (timely warning)

Rate how well the goggles performed in helping you to see eye-level hazards such as trees, branches, wires, poles, and vines.

1 2 3 4 5 6 7

(no forewarning) (timely warning)

Rate how well the goggles performed in helping you to see terrain contour hazards irregularities such as berms, side slopes, gullies, ditches, and cliffs.

1 2 3 4 5 6 7

(no forewarning) (timely warning)

Rate how easy it was to detect the targets with the goggles.

1 2 3 4 5 6 7

(difficult) (easy)

Rate how confident you felt walking around while wearing the goggles.

1 2 3 4 5 6 7

(hesitant) (confident)

Indicate the level of visual comfort (freedom from eye-strain, blurred vision, etc.) you experienced with the goggles.

1 2 3 4 5 6 7

(none) (continuous)

How often did the goggles allow adequate time to avoid the terrain hazards?

1 2 3 4 5 6 7

(never) (always)

APPENDIX B

QUESTIONNAIRE B

Questionnaire B

A Comparison Among the Three Goggles

Write "best" under the best of the three goggles; write "worst" under the worst of the three goggles on the following qualities.

	ANAVS6 Binocular	ANPVS7 Biocular	ANAVS6 (One Tube) Monocular
(1) Depth Perception	______	______	______
(2) Level of Comfort	______	______	______
(3) Target Detection	______	______	______
(4) Hazard Detection	______	______	______
(5) Environmental Awareness	______	______	______

(6) Write "best" under your first choice of goggles to wear during a night mission; write "worst" under your last choice.

	ANAVS6 Binocular	ANPVS7 Biocular	ANAVS6 (One Tube) Monocular
Choices	______	______	______

(7) For each time frame, write the number of times your wore night vision goggles; enter zero if you did not wear goggles during the time frame.

__ I wore goggles in August 1994.

__ I wore goggles in July 1994.

__ I wore goggles within the last year, but not since June 1994.

__ I wore goggles over one year ago.

(8) Write any additional comments about the strong points or shortcomings of the different goggles or problems that are common to all three goggles.

(Use the other side of the page if necessary.)

APPENDIX C

LANE WALKER'S SCORE SHEET

NIGHT VISION GOGGLES -- DATA SHEET

CONTACT WITH
EYE-LEVEL
HAZARD

CONTACT WITH
GROUND-LEVEL
HAZARD

CONTACT WITH
TERRAIN CONTOUR
HAZARD

MARKED
50% DECREASE
IN WALKING PACE

REQUEST FOR
ASSISTANCE

STOP

STUMBLE

OTHER

TARGET
DETECTION

(1)

(2)

(3)

(4)

(5)

(6)

(7)

Course | Goggles | Moonlight | Group | Participant's Identification

START TIME | END TIME | DATE | Participant's Name

APPENDIX D

TEST SEQUENCE

SEQUENCE OF TEST SESSION

START

INSIDE TENT

- Participants arrive and take the stride test.
- Participants sign Volunteer Agreement form.
- Snellen Vision Test and Stereoscopic Vision Test administered.
- Safety Brief & general goggle adjusting and focusing procedures explained.
- Goggles are donned by each participant.
- Adjust & focus goggle procedures explained in detail.

OUTDOORS

- Adjust & focus goggle procedures repeated.
- Snellen Vision Test repeated.
- Practice course is traversed.

OUTDOORS

• Participant No. 1	• Participant No. 2	• Participant No. 3
• Goggles & pedometers are donned.	• Goggles & pedometers are donned.	• Goggles & pedometers are donned.
• Course A traversed.	• Course C traversed.	• Course B traversed.
• Pedometer score recorded.	• Pedometer score recorded.	• Pedometer score recorded.
• Questionnaire A administered.	• Questionnaire A administered.	• Questionnaire A administered.
• Goggles & pedometers are donned.	• Goggles & pedometers are donned.	• Goggles & pedometers are donned.
• Course B traversed.	• Course A traversed.	• Course C traversed.
• Pedometer score recorded.	• Pedometer score recorded.	• Pedometer score recorded.
• Questionnaire A administered.	• Questionnaire A administered.	• Questionnaire A administered.
• Goggles & pedometers are donned.	• Goggles & pedometers are donned.	• Goggles & pedometers are donned.
• Course C traversed.	• Course B traversed.	• Course A traversed.
• Pedometer score recorded.	• Pedometer score recorded.	• Pedometer score recorded.
• Questionnaire A administered.	• Questionnaire A administered.	• Questionnaire A administered.
• Goggle comparison questionnaire administered.	• Goggle comparison questionnaire administered.	• Goggle comparison questionnaire administered.
• Eye dominance test.	• Eye dominance test.	• Eye dominance test.
END	END	END

APPENDIX E

ANALYSIS OF VARIANCE
(ERROR SCORES)

ANALYSIS OF VARIANCE
(ERROR SCORES)

Tests of Significance for ERROR SCORES Using UNIQUE Sums of Squares (No Moon Illumination)

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	2830.83	45	62.91		
GROUP	217.37	2	108.69	1.73	.189
ORDER	4.48	2	2.24	.04	.965
COURSE	23.15	2	11.57	.18	.833
*GOGGLE (1)	392.93	1	392.93	6.25	.016
*GOGGLE (2)	16.00	1	16.00	.25	.616

Tests of Significance for ERROR SCORES Using UNIQUE Sums of Squares (3/4 Moon Illumination)

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	1744.17	45	38.76		
GROUP	45.37	2	22.69	.59	.561
ORDER	7.70	2	3.85	.10	.906
COURSE	107.37	2	53.69	1.39	.261
*GOGGLE (1)	31.15	1	31.15	.80	.375
*GOGGLE (2)	25.00	1	25.00	.65	.426

*GOGGLE (1) is the contrast of the binocular goggle versus the unit of the biocular and the monocular goggles.

*GOGGLE (2) is the contrast of the biocular and the monocular goggles.

APPENDIX F

ANALYSIS OF VARIANCE
(TIME SCORES)

ANALYSIS OF VARIANCE
(TIME SCORES)

Tests of Significance for ELAPSED TIME Using UNIQUE Sums of Squares (No Moon Illumination)

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	8023142.83	45	178292.06		
GROUP	1830591.81	2	915295.91	5.13	.010
ORDER	768339.59	2	384169.80	2.15	.128
COURSE	213880.48	2	106940.24	.60	.553
*GOGGLE (1)	1303941.56	1	1303941.60	7.31	.010
*GOGGLE (2)	54366.69	1	54366.69	.30	.584

Tests of Significance for ELAPSED TIME Using UNIQUE Sums of Squares (3/4 Moon Illumination)

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	14886568.00	45	330812.62		
GROUP	4246417.15	2	2123208.60	6.42	.004
ORDER	400949.37	2	200474.69	.61	.550
COURSE	518953.81	2	259476.90	.78	.463
*GOGGLE (1)	79761.34	1	79761.34	.24	.626
*GOGGLE (2)	345156.25	1	345156.25	1.04	.313

*GOGGLE (1) is the contrast of the binocular goggle versus the unit of the biocular and the monocular goggles.

*GOGGLE (2) is the contrast of the biocular and the monocular goggles.

APPENDIX G

ANALYSIS OF VARIANCE
(HUMAN TARGETS)

ANALYSIS OF VARIANCE
(HUMAN TARGETS)

Tests of Significance for HUMAN TARGETS Using UNIQUE Sums of Squares (No Moon Illumination)

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELL	60.00	45	1.33		
GROUP	3.00	2	1.50	1.13	.334
ORDER	3.00	2	1.50	1.13	.334
COURSE	9.33	2	4.67	3.50	.039
*GOGGLE (1)	.00	1	.00	.00	1.000
*GOGGLE (2)	.00	1	.00	.00	1.000

Tests of Significance for HUMAN TARGETS Using UNIQUE Sums of Squares (3/4 Moon Illumination)

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	58.17	45	1.29		
GROUP	3.37	2	1.69	1.30	.282
ORDER	1.37	2	.69	.53	.592
COURSE	1.37	2	.69	.53	.592
*GOGGLE (1)	2.68	1	2.68	2.07	.157
*GOGGLE (2)	6.25	1	6.25	4.84	.033

*GOGGLE (1) is the contrast of the binocular goggle versus the unit of the biocular and the monocular goggles.

*GOGGLE (2) is the contrast of the biocular and the monocular goggles.

APPENDIX H

ANALYSIS OF VARIANCE
(SILHOUETTE TARGETS)

ANALYSIS OF VARIANCE
(SILHOUETTE TARGETS)

Tests of Significance for SILHOUETTE TARGETS Using UNIQUE Sums of Squares (No Moon Illumination)

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	24.00	45	.53		
GROUP	.26	2	.13	.24	.785
ORDER	1.81	2	.91	1.70	.194
COURSE	21.81	2	10.91	20.45	.000
*GOGGLE (1)	.93	1	.93	1.74	.194
*GOGGLE (2)	1.78	1	1.78	3.33	.075

Tests of Significance for SILHOUETTE TARGETS Using UNIQUE Sums of Squares (3/4 Moon Illumination)

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	41.50	45	.92		
GROUP	7.44	2	3.72	4.04	.024
ORDER	2.11	2	1.06	1.14	.327
COURSE	1.00	2	.50	.54	.585
*GOGGLE (1)	.33	1	.33	.36	.551
*GOGGLE (2)	.44	1	.44	.48	.491

*GOGGLE (1) is the contrast of the binocular goggle versus the unit of the biocular and the monocular goggles.

*GOGGLE (2) is the contrast of the biocular and the monocular goggles.

APPENDIX I

ANALYSIS OF VARIANCE
(QUESTIONNAIRE A)

ANALYSIS OF VARIANCE
(QUESTIONNAIRE A)

Tests of Significance for QUESTIONNAIRE A Using UNIQUE Sums of Squares (No Moon Illumination)

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	31.96	45	.71		
GROUP	13.93	2	6.96	9.81	.000
ORDER	1.47	2	.74	1.04	.363
COURSE	1.71	2	.85	1.20	.310
*GOGGLE (1)	17.58	1	17.58	24.75	.000
*GOGGLE (2)	.69	1	.69	.98	.328

Tests of Significance for QUESTIONNAIRE A Using UNIQUE Sums of Squares (3/4 Moon Illumination)

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	61.38	45	1.36		
GROUP	1.88	2	.94	.69	.507
ORDER	4.03	2	2.01	1.48	.239
COURSE	1.88	2	.94	.69	.507
*GOGGLE (1)	24.49	1	24.49	17.96	.000
*GOGGLE (2)	3.27	1	3.27	2.40	.128

*GOGGLE (1) is the contrast of the binocular goggle versus the unit of the biocular and the monocular goggles.

*GOGGLE (2) is the contrast of the biocular and the monocular goggles.

APPENDIX J

FRIEDMAN TWO-WAY ANOVA OF QUESTIONNAIRE B (NO MOON)

FRIEDMAN TWO-WAY ANOVA OF QUESTIONNAIRE B (NO MOON)

QUESTIONNAIRE B: NO MOON

Friedman Two-Way ANOVA

Mean Rank for Depth Perception

Binocular	2.69
Biocular	1.72
Monocular	1.58

Cases	Chi-Square	D.F	Significance
18	13.1944	2	.0014

Mean Rank for Level of Comfort

Binocular	2.28
Biocular	1.94
Monocular	1.78

Cases	Chi-Square	D.F	Significance
18	2.3333	2	.3114

Mean Rank for Target Detection

Binocular	2.39
Biocular	1.94
Monocular	1.67

Cases	Chi-Square	D.F	Significance
18	4.7778	2	.0917

FRIEDMAN TWO-WAY ANOVA OF QUESTIONNAIRE B (NO MOON) (Continued)

Mean Rank for Hazard Detection

Binocular	2.72
Biocular	1.67
Monocular 1.61	

Cases	Chi-Square	D.F	Significance
18	14.1111	2	.0009

Mean Rank for Environmental Awareness

Binocular	2.72
Biocular	1.72
Monocular 1.56	

Cases	Chi-Square	D.F	Significance
18	14.3333	2	.0008

Mean Rank Preference for a Night Mission

Binocular	2.67
Biocular	1.67
Monocular 1.67	

Cases	Chi-Square	D.F	Significance
18	12.0000	2	.0025

APPENDIX K

FRIEDMAN TWO-WAY ANOVA OF QUESTIONNAIRE B (3/4 MOON)

FRIEDMAN TWO-WAY ANOVA OF QUESTIONNAIRE B (3/4 MOON)

QUESTIONNAIRE B: 3/4 MOON

Friedman Two-Way ANOVA

Mean Rank for Depth Perception

Binocular	2.83
Biocular	1.53
Monocular	1.64

Cases	Chi-Square	D.F	Significance
18	18.8611	2	.0001

Mean Rank for Level of Comfort

Binocular	2.69
Biocular	1.72
Monocular	1.58

Cases	Chi-Square	D.F	Significance
18	13.1944	2	.0014

Mean Rank for Target Detection

Binocular	2.83
Biocular	1.47
Monocular	1.69

Cases	Chi-Square	D.F	Significance
18	19.1944	2	.0001

FRIEDMAN TWO-WAY ANOVA OF QUESTIONNAIRE B (3/4 MOON) (Continued)

Mean Rank for Hazard Detection

Binocular	2.78
Biocular	1.47
Monocular	1.75

Cases	Chi-Square	D.F	Significance
18	17.0278	2	.0002

Mean Rank for Environmental Awareness

Binocular	2.72
Biocular	1.58
Monocular	1.69

Cases	Chi-Square	D.F	Significance
18	14.1944	2	.0008

Mean Rank Preference for a Night Mission

Binocular	2.72
Biocular	1.61
Monocular	1.67

Cases	Chi-Square	D.F	Significance
18	14.1111	2	.0009

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